# ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY



PROJECT NO. 5 - CREW FATIGUE RESEARCH

Final Report On

Sub-Project No. 5-32, Driver Fatigue in Bendix Power Control Tank No. 908 as Compared with Standard M4A2 Medium Tank



Project No. 5-32



5 May 1943

ARMORED FORCE MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Project No. 5-32
749.2-12 GNOML

May 5, 1943

1. PROJECT: No. 5, Crew Fatigue Research. Final Report On: Sub-Project No. 5-32, Driver Fatigue in Bendix Power Control Tank No. 908 as Compared with Standard M4A2 Medium Tank.

a. Authority - Letter Headquarters Army Ground Forces, Army War College, Washington, D. C., 470.8/697 GNRQT-6/28516, dated January 17, 1943, and first Indorsement Armored Force Headquarters, Fort Knox, Kentucky, 470.8/3-112M4A2 (1-7-43) GNOHD, dated January 20, 1943.

b. Purpose - To determine driver fatigue in Bendix Power Control tank No. 908 as compared with a standard medium tank M4A2 over rough terrain requiring many turns and much shifting.

2. DISCUSSION:

a. Two types of experiment were run.

(1) A short run (0.6 miles in 4.5 minutes) was made over a predetermined course requiring a fixed number of turns and shifts, during which the work output was measured on each of two drivers alternately operating each tank.

(2) Tanks were run from 3 to 6 hours daily over bad terrain and measurements of fatigue were made during and after each run. The lead tank was changed every hour and drivers alternated tanks daily. Six such runs were made. The total mileage run per tank during the actual testing was 300 miles. Detailed results of the various test runs are presented in Appendix A.

b. During the tests the Bendix tank developed power difficulties once. In this instance a spot-weld which held a pulley to the generator broke. The tank was operated without difficulty on one pump for the rest of the day. A broken track and one bogey tire failure were the only other difficulties encountered with this tank.

c. Due to difficulties experienced with power trains, four standard M4A2 tanks had to be used for comparison with the Bendix Power Control tank. The breakdowns in these standard tanks did not result from the use of old, poorly maintained tanks. They were properly serviced in advance and the fourth was a new vehicle in excellent condition. The vehicles all broke down before it was possible to fatigue the drivers completely. Clutch

failure was experienced most frequently and in all cases, sooner or later (longest run over rough terrain without mishap, 6 hours) one or the other engine would stall when shifting down and frequently became so bad that only one gear could be used.

d. The test course (driving area 30, Fort Knox) consisted of wooded terrain without roads and with steep grades, deep gullies, sharp turns and deep mud. The worst part of the area was used at all times. On several occasions the standard tank bogged down in mud holes several feet deep. The Bendix tank, on the other hand, was able to negotiate these areas, due largely to greater ease of shifting and more positive and rapid brake action both of which enabled the vehicle to maintain way.

3. CONCLUSIONS:

From the point of view of driver fatigue, the Bendix Power Control tank No. 908 is better than the standard M4A2 medium tank.

a. Work output - The work output of the driver was 50% greater when operating the standard medium tank M4A2 than when driving the Bendix Power Control tank No. 908.

b. Fatigue - Driver fatigue in the Bendix Power Control tank No. 908 was not excessive. The fatigue resulting from driving the standard tank, if it could be run over such terrain for many hours without mechanical failure, would be excessive. On short runs of from 3 to 6 hours the driver of the standard tank showed higher pulse rates, had more symptoms of fatigue, and felt more tired than was the case when driving tank No. 908.

4. RECOMMENDATION:

a. From the point of view of driver fatigue, the installation of the Bendix Power Control in M4 medium tanks be considered as a desirable improvement. (Considerations of maneuverability, mechanical design and production and maintenance of the equipment are not within the scope of this report and will be reported upon by the Armored Force Board.

Submitted by:

William F. Ashe, Major, M. C.
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WILLARD MACHLE
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Commanding

4 Incls.
#1 - Letter of Authority
#2 - Appendix A
#3 - Table 1
#4 - Table 2

HEADQUARTERS
ARMY GROUND FORCES
ARMY WAR COLLEGE
Washington, D. C.

470.8/697 GNRQT-6/28516 Jan 17, 1943

SUBJECT: Service Test of Medium Tank M4A2 with Bendix Power Operated Controls.

TO : Chief of the Armored Force, Fort Knox, Kentucky.

It is desired that the Armored Force Board conduct service test on the Medium Tank M4A2 No. 908 equipped with Bendix Power Controls in general accordance with the data contained in the attached information sheet, Armored Force Board-80.

By command of LT. GEN. McNAIR:

/s/ C. H. Day
C. H. DAY
Colonel, A. G.D.
Asst. Ground Adj. Gen.

1 Incl.
Information Sheet
AFB-80 (dupl)

470.8/3-112M4A2 (1-7-43) GNOHD 1st Ind. S-2-28-43

HEADQUARTERS ARMORED FORCE, Fort Knox, Kentucky, January 20, 1943.

To: Commanding Officer, Armored Force Medical Research Laboratory, Fort Knox, Kentucky. THRU: President, Armored Force Board, Ft. Knox, Ky.

1. For compliance.

2. The Armored Force Board will cooperate with the Armored Force Medical Research Laboratory in furnishing of drivers and maintenance of the tank.

By command of Lieutenant General DEVERS:

/s/ C. M. Wells
C. M. WELLS
Lieut. Colonel, A.G.D.
Assistant Adjutant General

1 Incl: n/c

Incl. #1.

APPENDIX A

RESULTS

1. Driver Work Output.

a. Procedure - Each of two drivers drove both tanks, a standard M4A2 and the Bendix Power Control tank No. 908, over a fixed and very difficult course. They practiced until they could negotiate this course of 0.6 miles, with 18 sharp turns, continuous lesser steering adjustments, and 13 shifts, at a rate of 8 mph (The suggested rate of 15 mph was impossible over this course). After this practice period each driver made two (2) runs in each tank, during which the breathing rate and oxygen consumption were measured. The subject inspired outside air and exhaled into a Douglass bag. The expired air was mixed and 100 cc samples [two (2) for each trip] were collected. The content of the bag was then metered. The samples were analyzed in a Haldane gas-analysis instrument and the calories of work done were computed from the oxygen consumption data. The men had had no food or drink for four hours previous to the test runs and both had had equal practice handling each tank as well as breathing into the bag. Both were experienced drivers.

b. Results - Table 1 shows the results obtained. Subject Lat. produced 2.00 Cal/Kg/hr in the Bendix tank and 4.58 Cal/Kg/hr in the standard tank. Subject Nug. produced 3.25 Cal/Kg/hr in the Bendix and 4.82 Cal/Kg/hr in the standard tank. Thus, the work output was approximately 50% higher in the standard tank. This difference is significant. The higher value in the standard tank may be considered as moderately severe and would lead to serious fatigue if maintained for 8 to 10 hours. The lesser work required with the Bendix Power Control, on the other hand, could be continued for long periods without excessive fatigue.

2. Driver Fatigue.

a. Procedure - The two tanks were operated for 6 days over the test course, the daily run continuing for from 3 to 6 hours, depending upon mechanical failures. The two drivers alternated tanks daily during each test. The lead tank was changed every hour to equalize the more difficult driving in a following tank. Driving was suspended for 5 minutes each hour to make observations and the men were examined and questioned before and after each day's run. The following tests were carried out:

(1) Pulse rate (hourly during test)
(2) Subjective symptoms of fatigue and discomfort, as reported by driver
(3) Blood Pressure
(4) Circulatory System - effects of posture change on tilting table

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(5) Romberg test
(6) Pulse recovery rate after hopping on one foot 2 minutes
(7) Near and far point fusion
(8) Depth perception
(9) Horizontal and vertical eye balance
(10) A simple speed mental test
(11) Pass pointing

In no instance was it possible to get more than six hours continuous running because of mechanical failures in the standard tank. In all cases the tank broke down before the men were exhausted from the work. The test course was as bad as it was possible to find. It would be relatively difficult in good weather, and with the addition of much rain it became very difficult.

b. Results - Table 2 shows the comparative pulse rates of the men before and after driving each tank. In general the pulse rate of each driver was higher when driving the standard tank. Furthermore, on very hard runs, the pulse rate rose more sharply in the driver of the standard tank than it did in the driver of the Bendix tank.

Romberg test: Both men were able to stand on both feet without too much sway before and after driving either tank. However, both men failed to stand on one foot after driving the standard tank 4 hours or more, whereas, neither failed after driving the Bendix tank.

Neither driver showed any inclination to pass point at any time. No significant changes were noted in circulatory system response to posture change on the tilting table.

Driver Lat. showed definite loss of fusion at the far point after driving the standard tank but not on days he drove the Bendix tank. Driver Nug. showed loss of fusion at the far point after 4 or 5 hours of operation of both tanks.

Depth perception was normal in Nug. at all times. Lat. had poor depth perception before runs and did not seem to grow worse during them.

The Schneider pulse-recovery test showed nothing on Nug. On Lat., after driving the standard tank, his pulse was still 114 after 5 minutes. After driving the Bendix tank for the same length of time, his rate was 90 after 5 minutes. His peak pulse rate (130) was the same in both instances.

The eye-balance test showed nothing significant.

The mental tests showed no significant changes.

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It is apparent that in no instance were the men exhausted after driving either tank. Oxygen consumption measurement showed that much more work was done in the standard tank and in Table 2 one can see further evidence of this. One must conclude, therefore, that had we been able to operate long enough, much greater differences would have developed.

3. Maneuverability - At all times the Bendix tank was more maneuverable than the standard tank, in spite of the fact that the two tanks have the same power train and are therefore inherently capable of the same performance. The more rapid and positive action of the Bendix Power Control as compared with hand control results in more efficient use of the power available. Of considerable importance in determining the ease of maneuvering is the arrangement in the Bendix tank which enables the driver to apply braking to either or both tracks with the left hand alone, leaving the right hand free for shifting at all times. Thus, shifting is done with greater precision and without delay. Less shifting was required largely because speed was not lost on turns or while shifting. When climbing steep slippery grades, particularly at an angle, the Bendix tank was easily controlled while the standard vehicle tended to slip. The Bendix tank will make sharper turns and can complete a turn in much smaller space because of the more positive brake action. Both drivers felt strongly that the Bendix tank was not only easier to handle but that it could negotiate country through which the standard tank could not go and that it could maintain a higher average speed over rough terrain. The ease of maneuverability diminished both physical and mental fatigue.



Incl. #2

TABLE 1

COMPARATIVE DRIVER WORK OUTPUT
(M4A2 Tanks With and Without Bendix Power Control)

March 22, 1943
Bright Cool Day
Temp. 12.5-13.8°C (54-57°F)
Bar. - 744 Mm.

| Tank | Driver | Run | STANDARD TEMP. & PRESSURE | | | | R.Q. | $O_2$ Cal. per Liter | Cal/Kg/Hr. |
|---|---|---|---|---|---|---|---|---|---|
| | | | Ventilation, Liters per min. | Expired Air % $O_2$ | Expired Air % $CO_2$ | Liters $O_2$ used per min. | | | |
| Bendix | Lat | 1 | 14.98 | 4.60 | 3.69 | .684 | .802 | 4.80 | 2.99 |
| | | 2 | 14.92 | 4.72 | 3.59 | .702 | .761 | 4.75 | |
| Standard | Lat | 1 | 21.60 | 4.45 | 3.92 | .962 | .881 | 4.90 | 4.58 |
| | | 2 | 24.10 | 4.62 | 3.96 | 1.115 | .857 | 4.88 | |
| Bendix | Nug | 1 | 16.45 | 4.74 | 3.79 | .779 | .799 | 4.80 | 3.24 |
| | | 2 | 17.61 | 5.39 | 4.00 | .950 | .743 | 4.73 | |
| Standard | Nug | 1 | 24.9 | 5.15 | 4.00 | 1.282 | .777 | 4.78 | 4.82 |
| | | 2 | 25.1 | 5.20 | 3.80 | 1.302 | .731 | 4.71 | |

Incl. # 3

TABLE 1

TABLE 2

COMPARATIVE PULSE RATE CHANGES DURING DRIVING TESTS

(M4A2 Tanks with and without Bendix Power Control)

| Driver | Run | Pulse Before | Pulse After | Number Shifts | Distance Miles | Rate mph |
|---|---|---|---|---|---|---|
| Driving Standard Tank | | | | | | |
| Nug. | 1. | 93 | | 21 | 1 | 4 |
| | 2. | 93 | 126 | 74 | 8 | 8 |
| | 3. | 105 | 117 | 30 | 4 | 6 |
| | 4. | 102 | | 53 | 5 | 6 |
| | 5. | 96 | 123 | 68 | 9 | 9 |
| | 6. | 87 | 108 | 49 | 13 | 17 |
| | 7. | 90 | 120 | 82 | 7 | 8 |
| | 8. | 84 | 120 | 59 | 8 | 8 |
| | 9. | 86 | 135 | -- | 13 | 17 |
| Lat. | 10. | 90 | | 40 | 3.7 | |
| | 11. | 101 | 115 | 32 | 8 | 8 |
| | 12. | 102 | 112 | 65 | 8 | 8 |
| | 13. | 93 | 120 | 49 | 12 | 8 |
| | 14. | 90 | 120 | 73 | 6 | 7 |
| Driving Bendix Tank | | | | | | |
| Lat. | 1. | 85 | 96 | 14 | 1 | 4 |
| | 2. | 105 | 106 | 39 | 8 | 8 |
| | 3. | 84 | | 20 | 4 | 6 |
| | 4. | 105 | 103 | 53 | 5 | 6 |
| | 5. | 96 | 96 | 59 | 9 | 9 |
| | 6. | 88 | 90 | -- | 13 | 17 |
| | 7. | 90 | 105 | 74 | 7 | 8 |
| | 8. | 90 | 99 | 46 | 8 | 8 |
| | 9. | 90 | 99 | -- | 13 | 17 |
| Nug. | 10. | 88 | 114 | 32 | 3.7 | |
| | 11. | 96 | 116 | 33 | 8 | 8 |
| | 12. | 99 | 118 | 45 | 8 | 8 |
| | 13. | 90 | 105 | 36 | 12 | 8 |
| | 14. | 87 | 108 | 64 | 6 | 7 |

Incl. #4

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